LITERATURE REVIEW: SYNTHESIS

Project Report, August, 2008 REPORT 2A

John Pinnegar, CEFAS (editor)
Luc van Hoof, Wageningen IMARES, Project coordinator
Andy Payne, CEFAS
Audun Iversen, Fiskeriforskning
Chantal Cahu, Ifremer
George Tserpes, HCMR
Loïc Antoine, Ifremer
Maud Evrard, Marine Board
Véronique Lamblin, Futuribles

This report does not necessarily reflect the view of the European Commission and in no way anticipates the Commission's future policy in this area

The FEUFAR Project

Background

The goal of the project is to define the research required in the medium term (here taken as 10 years), to permit exploitation and farming of aquatic resources set against the context of key challenges and risks for meeting sustainability requirements. The main output of the exercise will be a publication outlining key challenges, strategic options and the research needs of capture fisheries and aquaculture in European waters and in waters in which European fleets operate under bilateral or multilateral agreements. The project is expected to contribute to the development and subsequent implementation of a European Maritime Policy and to further strengthen the European marine research area through anticipation of research needs in the field of fisheries and aquaculture.

Research Methodology

Basically, the methodology consists of three steps: (i) describe the system, (ii) detect the driving forces in the system and, (iii) by constructing hypotheses about the driving forces, sketch potential scenarios for the future. These different scenarios will provide the basis for the identification of issues, from an economical, ecological, societal and managerial (governance) perspective, which may need attention or be the key challenges in future. Based on the analysis, some of the key future needs for research in capture fisheries and aquaculture will be identified.

Contributions

FEUFAR will seek the opinions of appropriate stakeholders, and the analysis will consider the possible implications of gradual or catastrophic climate change, new technologies, changes in societal values and organizational structures, globalization of markets for fish and other marine products, food security and health, and changes in management practices or fishing techniques.

Stakeholder participation and dissemination of results is fully integrated into the project. An expert committee consisting of representatives of the research and funding communities will assist in providing feedback into the analysis, and stakeholder groups will be invited to formal brainstorming activities during the course of the project. One forum will set up a stakeholder network of representatives of research, industry and management areas at a regional, European and international scale. A second will take the form of an expert workshop, including a broad selection of (representatives of) research and advisory organizations across Europe. The wider audience (including Regional Advisory Council representatives, and hence representing production, processing, societal, and environmental interests) will be invited and/or consulted in order to present draft findings and to generate educated feedback.

CONTACT

You can log on to our project website where you will find more information about the project, the results of the activities as they become available, and a discussion forum: www.feufar.eu

Funded by:

Table of Contents

1 Preface

There have been a number of recent attempts to construct scenarios, and to define the key challenges and risks facing marine research over the next few years. Work package 1 of the FEUFAR project has been charged with reviewing 'Horizon Scanning' and 'Foresight' literature from around the world in order to identify common themes, perceived threats and worthwhile approaches, with specific relevance to the fisheries & aquaculture sectors. This work package has made use of relevant experience at the national level, in particular utilising outputs from 'Horizon Scanning' initiatives in the UK, Ireland, France, the Netherlands and Norway, as well as from further afield (e.g. New Zealand, Canada and Australia). The work package has considered whether threats and challenges identified in the existing literature might also be important within a wider European context.

2 A brief history of 'futures studies' and scenarios

'Futures studies' reflect on how today's changes (and continuities) become tomorrow's reality. The discipline includes attempts to analyze the sources, patterns, and causes of change and to map alternative futures. Futures studies are often summarized as being concerned with "three P's" or possible, probable, and preferable futures. Like historical studies that try to explain what happened in the past and why, the efforts of futures studies try to understand the latent potential of the present. This requires the development of theories of present conditions and how conditions might change. For this task, futures studies use a wide range of theoretical models and practical methods, many of which come from other academic disciplines including economics, sociology, engineering, and theology.

Two factors usually distinguish 'futures studies' from the research conducted by other disciplines:

1. futures studies often examine not only possible but also probable, preferable, and 'wildcard' futures
2. futures studies typically attempt to gain a holistic or systemic view based on insights from a range of different academic disciplines.

The following discussion, provides a brief history of futures studies and closely related work on scenarios.

The discipline is referred to by many different terms, depending on the cultural context. Such names include **future studies**, **foresight**, **horizon scanning, futurism**, **futurology**, **prospective** and **futuribles** (in France, the latter is also the name of an important 20th century foresight journal), and **prospectiva** (in Latin America). 'Futures studies' has become the common term in the English-speaking world.

The emergence of futures studies as an academic discipline, happened mostly after World War II. Differing approaches arose in Western Europe (mostly in France), in Eastern Europe (including the Soviet Union), in the post-colonial developing countries, and in the United States of America. In the 1950s European nations in particular, set about rebuilding their war-devastated continent, and in the process, academics, philosophers, writers, and artists explored what might constitute a long-term positive future for humanity as a whole, and for their own countries. The Soviet Union and the Eastern bloc countries participated in the European rebuilding, but did so in the context of an established national economic planning process, which also required a long-term, systemic statement of societal goals. The newly-independent developing countries of Africa and Asia faced the challenge of constructing industrial infrastructure from a minimal base, as well as constructing national identities with concomitant long-term social goals. By contrast, in the United States of America, futures studies as a discipline emerged from the successful application of the tools and perspectives of 'systems analysis', especially with regard to quartermastering the war-effort.

By the late 1960s, enough scholars, around the world had begun to question and explore possible long-range futures to form an international dialogue. Inventors such as Buckminster Fuller also began highlighting the effect technology might have on global trends as time progressed. This discussion on the intersection of population growth, resource availability and use, economic growth, quality of life, and environmental sustainability — referred to as the "global problematique" — came to wide public attention with the publication of *Limits to Growth* (Meadows &Meadows 1979). This international dialogue became institutionalised in the form of the World Futures Studies Federation (WFSF), founded in 1967.

Practitioners of the discipline previously concentrated on extrapolating present technological, economic or social trends. More recently they have started to examine social systems and uncertainties and to build **scenarios.** Along with extrapolation and the construction of scenarios, another widely-cited approach to divining the future is the 'Delphi method'. The **Delphi method** was developed over a period of years, at the Rand Corporation, for obtaining forecasts from a panel of independent experts (Rowe & Wright 1999, 2001).

A major part of scenario building involves connecting both extrapolated (exploratory) and normative research to help individuals and organisations to build better social futures amid a presumed landscape of shifting social and environmental changes. Practitioners use varying proportions of **inspiration** and **research** when devising scenarios. Several authors have become recognized as futurists, they research trends (particularly in technology) and write accounts of their observations, conclusions, and predictions. Some futurists share features in common with the writers of science fiction, and indeed some science-fiction writers, such as Arthur C. Clarke, have acquired a certain reputation as futurists. In a 1932 broadcast on the BBC, the visionary author H.G. Wells called for the establishment of "Departments and Professors of Foresight," presaging the development of modern academic futures studies by almost 40 years.

Many ‘futures studies’ have used **scenarios** - alternative possible futures - as an important tool. To some extent, people can determine what they consider probable or desirable using qualitative and quantitative methods. In the last decade, scenario methods, have become widely used in some European countries for policy-making. A **scenario** is an account or synopsis of a projected course of action, event or situations. Scenario development is used in policy planning, organisational development and, when organisations wish to test strategies against uncertain future developments. Scenarios are widely used by corporations to help understand different ways that future events could unfold. ‘Scenario planning’ or ‘scenario thinking’ is a complex process sometimes involving quantification, but often the elaboration of qualitative ‘storylines’.

The prime purpose of scenarios and scenario building is to enable decision-makers to detect and explore all, or as many as possible, alternative futures so as to clarify present actions and subsequent consequences. Scenarios support strategic thinking and decision making. Scenarios are imagined ‘futures’. They do not come singly, as a forecast would, but in sets of alternatives. Scenarios are not necessarily "visions" or "plans", but they can help to guide strategy (OST 1999). They describe both optimistic and problematic futures. Each may concentrate on a different driver of change (e.g. the drive towards sustainable development or material wealth) or a different area of influence (e.g. fisheries and aquaculture). Scenarios work well when they explore different ramifications and extensions of one central driving force. There is no temptation then to choose between them and they are all equally relevant (see below).

Good scenarios help us to understand how key drivers might interact and affect the future. Scenarios create representations of alternative worlds and can offer an inclusive and systematic way of thinking about what the future might look like. Scenarios go beyond a single best estimate, or a ‘high’ and ‘low’ projection, and encourage us to explore a number of different, logically-consistent (although not always desirable) pathways.

The wealth of recent experience suggests is that there is no single strategically best way to work with scenarios. However, well-designed scenarios do seem to share some common features (OST 1999):

- **DIY:** scenarios are best created by a panel - or at least commissioned and then explored and focused by a panel.

- **10 years distant, or longer:** scenarios are for the future that we cannot see, yet must still plan for. Their horizon is typically around ten years, though it may be as little as five when change is fast or chaotic, and as much as fifty when strong and unambiguous drivers are operating.

- **Credible:** scenarios are not forecasts. They can usefully examine fairly extreme sets of consequences. However, it is important that those involved feel comfortable with each scenario - however surprising, they should be able to imagine living in such a world.

- **Internally consistent:** it follows that the social, political, economic, environmental, technical and cultural features of a scenario should hang together, as they would if a piece of consistent history had been written leading up to that state of affairs.

- **Focused:** the best scenarios dramatise a few key features or events which are of prime concern.

- **Plural:** some groups have experimented with a unique scenario. This is usually a mistake, because a single view of the future is too easy to confuse with a forecast. The practitioners' consensus is that two is a minimum and, in the time usually available, four is a maximum.

- **Striking and sometimes uncomfortable:** one of the prime objectives of scenario work is to startle managers, fire their interest and get them thoroughly involved and excited. Scenarios should never be boring.

- **Dramatised:** scenarios work best when they are dramatised in various ways - brought to life by scene-setting, stories, case-studies metaphors or encapsulated in memorable and vivid catch-phrases (see section 1.6).

- **Altering plans and recommendations:** the acid test of good scenarios is that working with them changes the vision or plan that was proposed before the exercise. If one goes out by the same door that one went in, then the scenarios were probably too remote to have been useful.

As recognised by the United Nations Environment Programme (UNEP), in their handbook on methods for climate change impact assessment (UNEP 1998), it is “impossible to make a scenario of everything” and to encompass all possibilities. UNEP also state that ‘scenarios do not have to be developed from scratch;’ they can be borrowed or adopted from the literature, and this is the approach taken by many authors.

In 1997, the Intergovernmental Panel on Climate Change (IPCC) established an expert group to prepare global socio-economic scenarios (SRES) (IPCC 2000). Four main ‘storylines’ (with 40 variant scenarios) were developed, each describing possible future worlds and taking into account factors such as global population trends, economic growth and per capita income. These contrasting ‘storylines’ have subsequently proven to be of great utility, and they have formed the basis of many regional or national-scale evaluations.

3 Scenario exercises of relevance to fisheries & aquaculture

There have been many attempts (in Europe and elsewhere) at predicting the future prospects of industries in the marine environment. The fisheries and oil sectors in particular, have received much attention. A search of the global 'futures' literature has revealed more than 26 studies which consider the future of the fisheries and aquaculture sectors, and these studies can be divided into four broad types (table 1), namely: those which consider the whole marine environment, those which provide specific scenarios for fisheries and/or aquaculture, those which constitute personal visions of the future, and those primarily concerned with establishing research priorities.

Many 'futures' studies exist which mention fisheries and aquaculture, but only in the context of much broader, holistic scenarios for the marine environment. Examples of this type include the recent scenarios report of the *Millennium Ecosystem Assessment* (MEA 2005), the *ELME* report on 'European Lifestyles & Marine Ecosystems' and the *Global Environmental Outlook* of the United Nations Environment Program (UNEP 2002). Some studies provide very detailed visions of the marine environment in particular countries, notably the GAUFRE scenarios from Belgium (Maes et al. 2005), the AFMEC scenarios (Pinnegar et al. 2006) for the UK, and the cross-cutting marine scenarios developed in New Zealand (PCE 1999). Often, fisheries and aquacutlure are only mentioned in very brief terms, however in some of these studies (in particular the *Millennium Ecosystem Assessment* and AFMEC), these sectors are examined in considerable detail with specific visions for particular fleets and/or aquaculture types. The GAUFRE scenarios are unusual in that they explicitly consider the spatial dimension, with an assessment of the extent of fishing and aquaculture activities (among others) in the coastal waters of Belgium. The *ELME* study (Langmead et al 2007) outlines the likely direction of change (large increase, increase, stable, decrease, large decrease) for particular 'drivers' (including fishing effort), 'pressures', and 'states' in each of four European regional seas (Baltic, Black Sea, Mediterranean, NE Atlantic) drawing heavily on lessons learnt from earlier futures studies such as AFMEC and IPCC-SRES (IPCC 2000).

Table 1. 'Futures studies' of relevance to marine fisheries & aquaculture.

Holistic scenarios for the marine environment	Specific scenarios for fisheries & aquaculture	Personal visions for fisheries & aquaculture	Research priorities
AFMEC (UK) (Pinnegar et al. 2006)	*Fish to 2020* (Worldfish) (Delgado et al. 2003)	Pauly et al. (2003)	Sea Change: a marine knowledge & innovation strategy or Ireland (Marine Institute 2006)
GAUFRE (Belgium) (Maes et al. 2005)	*Net Benefits* (UK) (Prime Minister's Strategy Unit 2004)	Garcia & Granger (2005)	Canada's "*Marine & Ocean Industry Technology Roadmap"* (NRC 2003)
Millennium Ecosystem Assessment (UN) (MEA 2005)	*Aquaculture 2020* (Norway) (NRC 2005)	Bruun et al. (2002)	*Knowledge & Innovation Priorities* (Netherlands) (NRLO 1998)
Global Environment Outlook (UNEP 2002)	*State of World Fisheries & Aquaculture* (FAO 2004)	Pope (1989)	Australia's "Marine Science & Technology Plan" (COA 1999)
Setting course for a sustainable future (New Zealand) (PCE 1999)	NRLO – *Fishing for Research* (Netherlands) (Jagtman et al. 1997)	Daan (1989)	Aquaculture & fisheries in southern countries: prospective analysis of the research demand by 2025 (France) (IFREMER 2002)
ELME – European Lifestyles & Marine Ecosystems (Langmead et al. 2007)	*Future Fish* - Pew Initiative on Food and Biotechnology (Pew Initiative 2003)		*Fisheries 2027* - a long term vision for sustainable fisheries (UK) (Defra 2007a)
	Modelling Australia's fisheries to 2050 (Kearney et al. 2003)		
	Ross & Rosenthal (2006)		
	5 Scénarios pour la pisciculture Français en 2021 (INRA 2007)		

A second group of 'futures' studies are those which set out to provide scenarios for the fisheries and aquaculture sectors specifically, these include national visions (*Net Benefits*-UK, *NRLO- Fishing for Research, Modelling Australia's fisheries, Scénarios pour la pisciculture Français*) and those striving to provide a global outlook ('FAO-SOFIA', '*Fish to 2020*'). Three of the studies identified ('*Future Fish', Scénarios pour la pisciculture Français* and '*Aquculture 2020*') focus solely on aquaculture, whereas most of the others consider both fisheries and aquaculture.

The *Net Benefits*-UK (Prime Minister's Strategy Unit 2004), NRLO- *Fishing for Research* (Jagtman et al 1997) and *Modelling Australia's fisheries* scenarios (Kearney et al. 2005) each consider what the fishing fleets of the particular counties might look like under certain storylines (usually including a 'liberalised markets' scenario, an inward-looking 'nationalist' scenario, and a 'global sustainability' scenario). Each of these studies considers what the consequences might be in terms of imports, exports, subsidies, profits, and fleet decommissioning/expansion.

The '*Fish to 2020'* (Delgado et al. 2003) and 'FAO-SOFIA' (FAO 2004) scenarios consider global patterns of demand and consumption of fish products. These studies attempt to predict the relative importance of wild capture-fisheries versus aquaculture as well as potential sources of industrial fish-meal and oil over the next 20 years. These studies anticipate growth in demand for fish products in China and the 'developing world', and the likely difficulties faced at a global level in procuring sufficient supplies of fish in the future.

The '*Future Fish'* scenarios of the Pew Initiative on Food & Biotechnology (Pew Initiative 2003) are somewhat peculiar, in that they specifically focus on a single issue; the possible escape of transgenic fish from aquaculture and the possible implications this might have for wild fish populations. Other 'single-issue' scenarios of relevance to fisheries and aquaculture include those of Ross & Rosenthal (2006), focussing and trade between developing countries and countries in the European Union.

The French Institut National de la Recherce Agronomique (INRA) published 5 scenarios specifically for pisciculture (aquaculture based on fin-fish) up to the year 2021 (INRA 2007). After identification of key driving forces, 18 partial scenarios were combined into 5 basic storylines, which can be broadly characterised as: (1) changes at the global level lead to a national reprioritization, (2) liberalized world markets, (3) environmental focus forces aquaculture elsewhere, (4) European control and encouragement, (5) technological development, driven by consumers and convenience, solves all the problems.

A third major group of 'futures studies' are those which might best be described as **personal visions**, usually of well-respected fishery and aquaculture scientists, and benefiting from many years of accumulated insight.

In the pages of the journal *science* in 2003, Daniel Pauly (and his co-authors) set out his vision of the future of fisheries and aquaculture world-wide, drawing heavily on earlier work by the UN Environment Programme (UNEP 2002). This work acted as a precursor to the *Millennium Ecosystem Assessment* scenarios (MEA 2005), with which Pauly was also involved.

Garcia & Granger (2005) provide a detailed account of long-term trends in global fisheries, aquaculture, food security, trade, technology and fleets as well as reviewing past attempts to predict the future for this sector. These authors provided a reasoned account of what might be expected under a 'business as usual' or 'best guess' scenario (market-driven fisheries world), as well as what might be anticipated under a 'worst case' (feudal fisheries world) and 'best case' (responsible-fisheries world) scenario. This study highlighted the main driving forces likely to influence the future of marine capture fisheries and posed a number of hither-to unanswered questions. Garcia & Granger (2005) drew direct comparisons between their scenarios and those put forward by other experts and authors, notably those of Pope (1989), Daan (1989), Ikeda (1998), Becket (1998) and Cury & Cayré (2001).

Without specifying a reference time horizon, Daan (1989) speculated about the future of the North Sea. Having identified the current problems, he described three possible options for the future: (i) doing nothing, (ii) doing the impossible, and (iii) doing one's best. Pope (1989), publishing in the same special issue of the journal *Dana,* ventured into predicting four caricature scenarios for the North Sea which, with minor modifications, could be considered as possible scenarios for all or many of the world's fisheries. The paper highlights the interactions between the overall economic situation and global climate change with national objectives for fisheries, ranging from maximizing recreational benefits to ensuring basic fish protein for a poor population lacking alternatives.

In a special issue of the *Journal of the Northwest Atlantic Fisheries Society,* Ikeda (1998) and Becket (1998) each put forward their own perspective, with particular reference to 'the future of marine capture fisheries'. Ikeda (1998) presented a not-too-optimistic view of potential development up to 2010 with special reference to Japan. He reckoned that demand would increase globally and that rising fish prices would continue to provide incentives to fishers to increase pressure globally. He predicted that overfishing and increased capture of juveniles will follow, encouraged by buyers and importers. Contrary to the standard assumption, Ikeda suggested that that aquaculture, affected by pollution, diseases, shortage of feeds and water supplies will not be able to fill the fish supply gap. Ikeda foresaw a reinforcement of environmental protection regulations, better science, development of compensatory schemes for displaced fishers, and better use (less waste) of fish products, aiming at a priority of human consumption.

Becket (1998) took the unusual perspective of looking back from the year 2025, and considering the series of events (actual and fictional) which occurred over the previous 50 years. Major influences included changes in cultural attitudes, international treaties and legislation, developments in fishing gear, the growth of knowledge and the understanding of ecosystems.

Cury & Cayre´ (2001) provided a similar, retrospective description of the evolution of fisheries, supposedly written in 2051, and indicated that "marine capture fisheries disappeared as a professional activity, c. 2020". Drawing a parallel with the end of hunting, they indicate that fishing disappeared, under societal pressure from young generations of stakeholders, discredited by conflicts, overexploitation, overcapitalization, demographic pressure, non-precautionary management and development, lack of stewardship, inappropriate institutions and climate change. These pressures and driving forces led to irreversible depletion of most resources. Technological innovations outpaced scientific capacity to predict and institutional capacity to adapt. Science was wasted in conflicts with NGOs and conservation agencies. Long- and short-term objectives could not be reconciled. Fishing rights and eco-labelling failed to provide the proper incentives. Fish prices increased dramatically, turning high-value species into luxury items for developed countries' wealthy consumers, leaving only small pelagic and invertebrate prey species to the less well endowed.

Bruun & Hukkinen (2002) provided a set of equally imaginative scenarios for aquaculture in the Finish Archipelago Sea. These authors argue for a plurality in 'futures' approaches, including conventional scenarios (contingent developments) but also unconventional scenarios (sudden 'shock' events). The 7 scenarios proposed were constructed as a series of stories or narratives, some including one-off catastrophic events such as collisions between Russian oil tankers or health scares.

The fourth major grouping of 'futures studies' focussing on fisheries and aquaculture are those primarily concerned with **establishing research priorities.** Many countries have undergone a period of reflection in recent years, and there are useful 'horizon scanning' documents available for Ireland, the Netherlands, the UK, Canada, Australia and France. These documents can themselves be divided into two broad types, those primarily concerned with a long-term vision for sustainable fisheries (e.g. the UK 'Fisheries 2027' study) and those concerned with mapping research priorities and new technologies.

In 2007 the UK government published a document called "*Fisheries 2027: a longer-term vision for sustainable fisheries"* (Defra 2007a). In this document the government set out it's vision for marine capture fisheries up to the year 2027, drawing on earlier scenarios work (Prime Minister's Strategy Unit 2004). This document included 'statements' regarding future rights of access to fisheries, responsibilities of different stakeholder groups, fleet economics, social consequences and acceptable environmental impacts. This study was soon followed by a 'draft implementation plan' (Defra 2007b), which set out proposals for delivering the 'Fisheries 2027' vision, including proposals for actions over the next 5 years, key targets and commitments to improving science and its credibility among stakeholders.

The National Council for Agricultural Research in the Netherlands carried out a similar strategic evaluation of the fishing industry in 1998 (NRLO 2002). This study centred on the 'impact of development' on the fish industry as a whole, including policy implications and needs for research. The stated aim of the study was to set the policy agenda, especially towards research, hence it was targeted at an audience of policy makers and those influencing the policy agenda. The study considered trends in markets, ecology, fish stocks, space utilisation and water usage. Research priorities were considered as a result of the analysis made, although there was no stand-alone analysis of research drivers and developments.

Similarly, Ifremer (the primary fisheries research organization in France) carried out a foresight exercise aimed at evaluating the future research needs of Southern countries (in the developing world), with regard to marine aquaculture and fisheries, and to estimate the capacity of Ifremer scientists to address such issues (IFREMER 2002). The report analysed the potential skills and expertise of Ifremer scientists in aquaculture and fisheries, previous experience, cooperative studies and contracts in southern countries. Different scenarios of change were examined and their consequences in terms of research needs in the different areas were projected. A set of 16 drivers were selected, pooled in 3 main categories: drivers linked with the "living world", drivers linked with "Matter and technology", and drivers linked with "Society". Consequences for aquaculture and fisheries were projected in 3 scenarios named as: (i) continuation of present trends; (ii) optimistic scenario, (iii) pessimistic scenario. Each scenario was applied in the 5 main geographic areas.

In 2006 the *Marine Institute* (of Ireland) produced a document called "*Sea Change: a marine knowledge & innovation strategy for Ireland 2007-2013"* (Marine Institute 2006). This included a vision of the future up to 2020 and research needs for ports & shipping, seafood processing, finfish aquaculture, shellfish aquaculture, fisheries resources, seaweed resources, offshore oil & gas, marine 'functional foods', renewable ocean energy, rapid climate change. The Strategy was aimed at ensuring that Ireland fully maximizes the economic, social and environmental contribution of its marine resources in a manner similar to countries such as Denmark, the Netherlands and Norway. Furthermore, it placed great emphasis on marine activities as a driver of regional development. The report provides a profile of existing marine research in Ireland and the current level of investment before outlining objectives, opportunities & challenges and 'key research programme outputs' spanning 2007-2013. It also suggests investment requirements, implementation goals, performance measures and means of tracking progress towards the stated long-term objectives.

A similar in-depth exercise was carried out in Australia, to produce the county's "Marine Science & Technology Plan" (COA 1999). The Plan defines twenty-nine objectives for the national effort in marine science, technology and engineering, through three integrated programs:

1. Understanding the marine environment;
2. Using and caring for the marine environment; and
3. Infrastructure for understanding and utilising the marine environment.

The plan aims to guide the development of sustainable maritime industries in the context of ecosystem-based and multiple-use management regimes. It presents proposals for integrated and innovative science and technology. It also addresses the nations ability to meet international commitments, and the need to encourage effective community participation.

Canada's "*Marine & Ocean Industry Technology Roadmap"* (NRC 2003), offers a vision whereby the country will become an internationally recognized centre for marine and ocean industry technologies by the year 2012. With regard to fishing and aquaculture, the vision would see coastal communities making a strong comeback. This comeback would be based largely on success in aquaculture and shell fishing. There is also potential for a substantial revival of the fin-fish industry through the application of new ecosystem-based management techniques. These include the use of advanced ecosystem modelling, the development and management of marine protected areas, and broadly based restoration activities. Significant systems engineering improvements are anticipated in aquaculture technology including cages, feeding systems, electronic monitoring, fish health, and reducing the negative environmental impacts.

In order to summarize the key attributes of each 'futures' study a standard 'template' was devised (figure 1). This has been completed for each of the 26 studies identified (annex 1-26), and includes information on:

1. The report title
2. An identifying short title
3. The report authors
4. The written source (book, report etc.)
5. The geographic scope of the study
6. The focus & disciplinary scope
7. The stated objectives of the study
8. Time horizon over which predictions are made
9. The methods employed to construct scenarios
10. Whether any consultation was involved
11. The main drivers considered
12. The scenario structure or architecture
13. Whether shocks & catastrophes were considered
14. Any unique selling points of the particular study
15. Whether research drivers and/or priorities were considered
16. Possible recommendations made in the study or further uptake.

In the following sections we consider the main lessons that have been learnt from an overview of the different studies, in particular we highlight commonalities in the architecture that has been adopted by many of the studies, and we consider whether it is advisable to offer a 'best guess' or 'business as usual' scenario.

3.1 How likely are the scenarios?

Some 'futurists' have chosen to offer a 'best-guess' scenario (e.g. the *'Fish to 2020'* scenarios of Delgado *et al.* (2003), and the French '*Aquaculture & Fisheries in southern countries'* scenarios – IFREMER 2002), i.e what the authors judge to be the most likely future outcome. Whether or not to use a "best guess", "business-as-usual" or "central" case scenario was a conundrum faced by the IPCC when developing their SRES storylines (IPCC 2000) and also a conundrum which became apparent in many of the studies developing scenarios for fisheries and aquaculture.

The problem with this approach, is that readers tend to confine their attention only to the 'best-guess' when this is presented and do not consider the other plausible outcomes. Thus by simply labelling one vision as 'best-guess' or 'business-as usual' readers become blinkered to the full range of possibilities and complacent about the inherent unpredictability of the future. Also, an even number of scenarios helps to avoid the impression that there is a "central" or "most likely" case. When presented with three scenarios, readers tend to focus their attention on the one they perceive as being in the middle, with the others considered as extreme (and therefore unlikely) variants.

In preparing their SRES scenarios (IPCC 2000), the International Panel on Climate Change have always maintained that it is not possible to attach objective probability estimates to their four basic storylines. However, in a dialogue which erupted in the pages of the scientific journal *Nature* in 2001 (Schneider 2001, Pittock et al. 2001; Grűber & Nakicenovic 2001), one expert argued that policy analysts needed probability estimates in order to assess the seriousness of the implied climate impacts and hence act to mitigate these (Schneider 2001).

In a reply several weeks later, Grűber & Nakicenovic (2001) argued:

"Although we agree with most of what Schneider says, we disagree with him about the appropriateness and feasibility of assigning subjective probabilities of occurrence to alternative, unknown futures described by the SRES scenarios. In an interdisciplinary scientific assessment, the concept of probabilities as used in natural sciences should not be imposed on the social sciences. Probability in the natural sciences is a statistical approach relying on repeated experiments and frequencies of measured outcomes, in which the system to be analysed can be viewed as a 'black box'. Scenarios describing possible future developments in society, economy, technology, policy and so on, are radically different. First, there are no independent observations and no repeated experiments: the future is unknown, and each future is 'path-dependent': that is, it results from a large series of conditionalities ('what if… then' assumptions) that need to be followed through in constructing internally consistent scenarios. Socioeconomic variables and their alternative future development paths cannot be combined at will and are not freely interchangeable because of their interdependencies. One should not, for example, create a scenario combining low fertility with high infant mortality, or zero economic growth with rapid technological change and productivity growth — since these do not tend to go together in real life any more than they do in demographic or economic theory. – There is a danger that Schneider's position might lead to a dismissal of uncertainty in favour of spuriously constructed 'expert' opinion."

Of the 26 studies reviewed here, only 4 have chosen to specifically include a 'best guess' or 'business as usual' scenario, notably those of Garcia & Granger (2005), Maes et al. (2005) [ELME], IFREMER (2002), and Delgado et al . (2003) [*'Fish to 2020*]. However, Garcia & Granger anecdotally align their 'business as usual' scenario with those of other futures studies which encompass liberalised markets. Thus the authors believe that the current socio-political environment tends most towards the direction of free-trade and 'world markets' world vision, and as such their 'business as usual' scenario is broadly compatible with the UK-AFMEC 'world markets' scenario, the NRLO (1997) 'drifting fleet' scenario, the UNEP 'markets-first' scenario, the UK – *Net Benefits* 'market world' scenario and the *Millennium Ecosystem Assessment* 'global-orchestration' scenario. Pinnegar et al (2006) also believed that current trends seem to point most towards a 'world-markets' direction, but with aspects of all four possible futures also apparent. The authors of the ELME study (Langmead et al. 2007) followed suit but created a fifth distinct scenario between the 'World Markets – growth is good' and 'National Enterprise – pull up the drawbridge' futures, which they labelled as 'Baseline – current best guess'. An analysis of public opinion regarding socio-economic scenarios in the UK (including those upon which the AFMEC and ELME marine scenarios were based), revealed that only the World-Markets scenario was instantly recognizable to most people consulted. Work by CSERGE at the University of East Anglia, found that a 'global-sustainability' vision was also widely recognizable, however questions were raised about the plausibility of the introvert, nationalist scenarios and particularly when applied at the regional level (Shackley & Wood 2001).

3.2 Lessons Learnt: Architecture

Many existing scenario exercises, whether coincidentally or not, seem to have also chosen similar criteria to define their 'possibility-space', with an axis representing 'local to global' and an axis representing societal/economic intervention (from tight control to liberalisation). Conveniently, in broad terms, this means that many existing scenarios for fisheries and aquaculture, can be mapped onto one another (e.g. Table 2).

The four-quadrant approach (figure 1), whereby the future 'possibility-space' is divided, based on two axes or dimensions has become commonplace following its earlier adoption by the Intergovernmental Panel on Climate Change (IPCC). The basis of the 4-quadrant model is the identification of the two driving forces with the perceived greatest importance and the highest uncertainty.

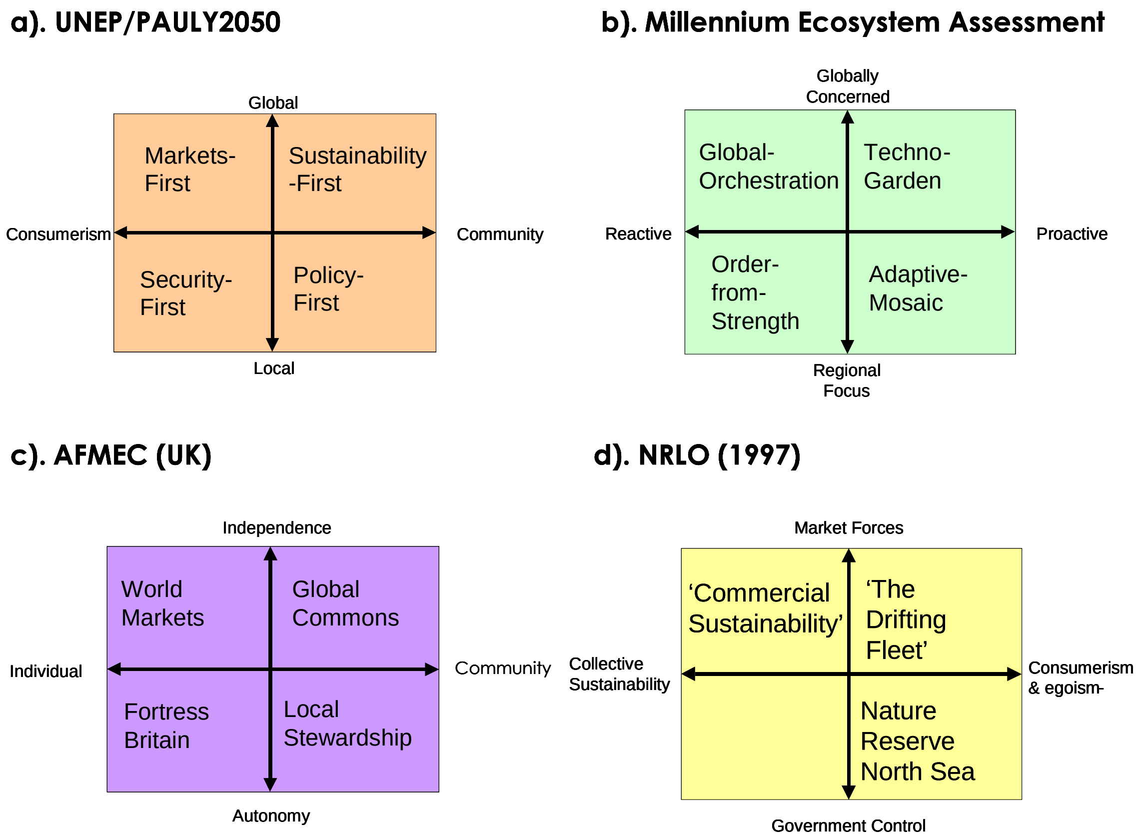

Figure 1. Four scenario schemes which use similar 'architecture'

As recognised by the United Nations Environment Programme (UNEP), in their *handbook on methods for climate change impact assessment* (UNEP 1999), 'scenarios do not always have to be developed from scratch;' they can be borrowed or adopted from the literature. Futurists are 'strongly advised to rely on existing scenarios to save time and to be comparable and consistent'. Broadly speaking the scenarios chosen by most authors can be characterised as follows:

A **'world-markets'** scenario, within which people aspire to personal independence, material wealth and greater mobility, to the detriment of wider societal and environmental goals. The market is 'all powerful' and unrestrained.

A **'global-stewardship'** scenario which assumes that people aspire to high levels of welfare and a sound environment. There is a belief that these objectives are best achieved through cooperation at an international level.

A **'nationalistic'** scenario which assumes that people aspire to personal independence and material wealth within a nationally-rooted cultural identity. Conservation and sustainable development are not a main priority whereas security of indigenous supplies is very important.

A **'local-stewardship'** scenario which assumes that people aspire to sustainable levels of welfare in local communities. Active public policy aims to promote economic activities that are small-scale and regional in scope, and acts to constrain large-scale markets and technologies. Under this scenario pressure continues to protect but also to exploit indigenous marine resources, and this results in a diverse range of impacts with some marine areas becoming degraded, while others see great improvements. Local action fails to address large-scale global environmental concerns.

3.3 Lessons Learnt: Symmetry

It helps to have a clear structure/architecture– so that the storylines constructed are consistent and not contradictory. Almost all of the scenario projects reviewed here have used some sort of guiding 'architecture', usually (but not always) involving two main axes – and hence have resulted in four main storylines (figure 1 and table 2).

In reality there are an infinite number of possible 'futures' (a multidimensional 'possibility-space') and some scenario exercises have developed separate (though still internally consistent) variants of one or several of the four main visions. The IPCC SRES scenarios for example, consist of 4 main visions, but the A1 storyline (equivalent to 'world-markets') is divided into three variants, labelled A1FI (intensive fossil fuel use), A1T (non-fossil energy sources), and A1B (a balance of energy fuels). Similarly, Pope's (1989) three main scenarios for the North Sea can be divided into 8 distinct variants on the basis of climate change but also assumptions about the global economy.

Several authors have defined their scenarios depending on the uptake and reliance on new technologies (notably the Millennium Ecosystem Assessment (MEA 2005) and Constanza 2000), whilst others have created variants with or without a particular sudden event occurring and subsequent feedbacks (see below).

A review of the global 'futures' literature identified five main dimensions of choice: demography and settlement patterns; the composition and rate of economic growth; the rate and direction of technological change; the nature of governance (global to local); and social and political values (individualistic or community) as the most commonly adopted (Berkhout & Hertin 2002).

For a number of reasons it would seem that the last two have been considered the most relevant dimensions in the majority of studies (including most aquaculture and fisheries scenarios). Economic growth can be regarded as the outcome of a set of institutional factors (economic and monetary policy, trade, the liberalisation and regulation of markets and so on), not as an autonomous factor of change. Likewise, technology is often regarded as being shaped by markets, regulatory, political and cultural factors and hence should not be seen as an autonomous factor of change. Consequently many marine scenario studies have sought to include technology as endogenous to the processes of social and technological change – an outcome, rather than an exogenous input.

Unusually among 'futures' studies, the Belgian GAUFRE project (Maes et al. 2005) has chosen to base it's scenario architecture around three structuring dimensions rather than two, and this has resulted in six distinct future visions as opposed to the usual four. Particular futures are viewed as being characterised by combinations of three key variables/drivers (well-being, economic value, ecological & landscape value) (figure 2 and 3). Scenarios involving the designation of marine protected areas, for instance, would be particularly related to the weight that policy makers put on the ecological and landscape value, whereas scenarios emphasising sand and gravel extraction would be linked to the perceived importance of the economic value of the North Sea. These three dimensions outline the 'parameter-space' for the 6 GAUFRE scenarios. Schematically, the six scenarios are presented on the six angles of a hexagon (see below) with different emphasis being placed on each of the three 'axes' under each of the six scenarios (figure 3).

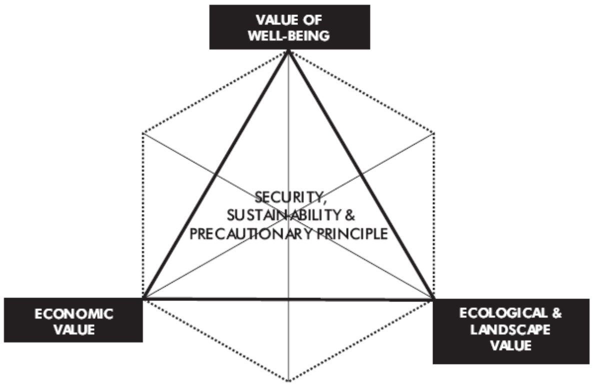

Figure 2. Schematic illustration of the three main 'axes' used to define scenarios in the Belgian GAUFRE study. "Well-being" recognises the potential value that society might place on the North Sea as an area for recreation. "Ecological & Landscape value" recognises the 'natural wealth' of the North Sea, including highly diverse networks of benthos, fish, marine mammals and birds. It also recognises 'heritage value' including the importance of protecting ship-wrecks and landscapes etc. "Economic value" recognises the financial 'goods' and 'services' provided by the North Sea. Scenarios which emphasise this aspect, strive for greater utilisation – including making the most of sand and gravel resources, fish stocks and renewable energy opportunities. The North Sea is recognised as being important for the transport of goods and passengers.

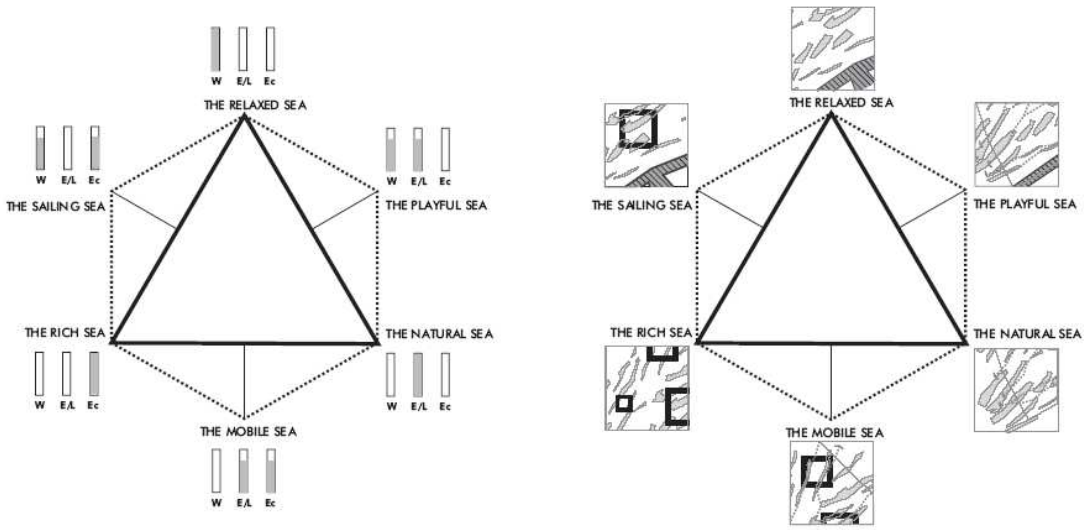

Figure 3. The six GAUFRE scenarios, 'mapped' onto the three structuring axes (above).

A broadly similar 'mapping' exercise has been carried out with the four *Millennium Ecosystem Assessment* (MEA 2005) scenarios, whereby each scenario gives greater or lesser emphasis to each of five key variables or attributes. These five 'axes' are: Material Well-being, Social-Relations, Freedom of Choice & Action, Security, and Health (figure 4).

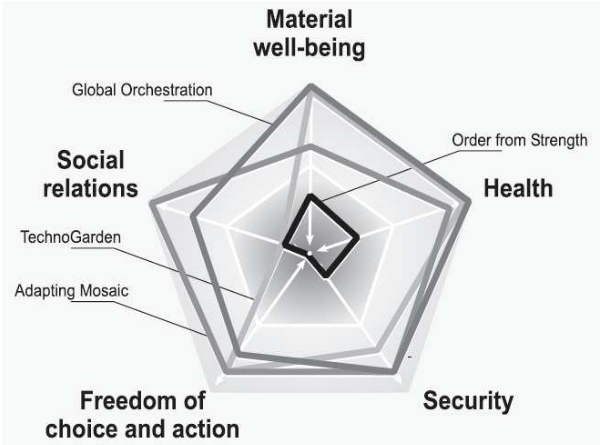

Figure 4. *Millennium Ecosystem Assessment* scenarios. The pentagon in the middle represents the situation in 2000. Moving outward from that indicates an improvement in that particular component of human well-being in that scenario by the year 2050. Moving inward from the pentagon indicates a decline in that aspect of human well-being since 2000.

Garcia & Granger (2005) attempt to illustrate their own three scenarios using a similar technique, with different shaped polygons indicating emphasis on particular attributes. In this case, the illustrative polygons have 16 'dimensions', with current trends pulling in many directions. In this framework, the direction of the present forces for change (the direction of ongoing trends) has been indicated. The figure illustrates the fact that the present situation is characterized by contradictory forces. While the agreed conceptual objectives for fisheries policy pull the system towards the best case values (in the centre of the figure), the short-term economic reality and the effects of globalization and market domination pull, in many cases, in the opposite direction.

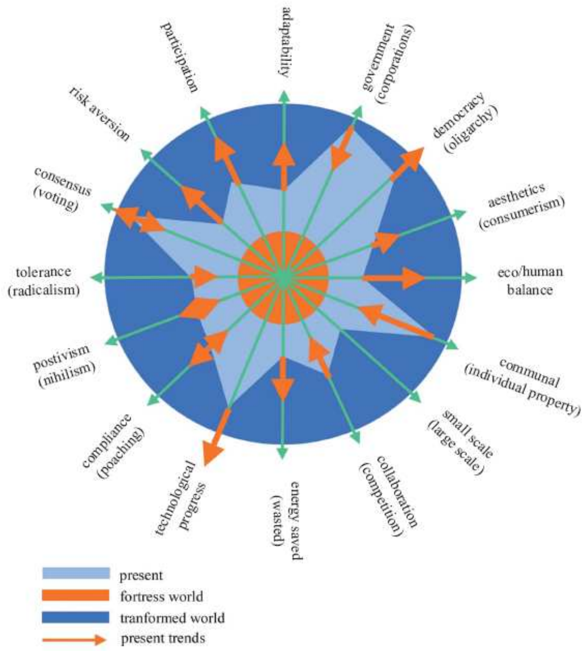

Figure 4. Main characteristics of the scenarios proposed by Garcia & granger (2005)

Table 2: Broad correspondence between scenarios developed for fisheries and aquaculture.

IPCC - SRES Storyline	Millennium Ecosystem Assessment	UK-AFMEC	*UK Net Benefits*	*UNEP/Pauly-2050*	*Garcia & Granger*	*NRLO-Fishing for Research*	*ELME (European Lifestyles & Marine Ecosystems)*	*Havbruk 2020-* Norway
B1	Techno-Garden	Global-Commons	Green-World	Sustainability First	'Best-case' (Transformed world)	Commercial sustainability	Global Community	Sustainability
B2	Adaptive-Mosaic	Local-Stewardship	-	Policy-First	-	Nature Reserve North Sea	Local Responsibility	Feed for all
A2	Order-from-Strength	Fortress-Britain	Fortress-Europe	Security-First	Worst-case (Fortress world)	-	National Enterprise	Markets without boundaries
A1FI	Global-Orchestration	World-Markets	Market-World	Markets-First	'Business as usual' (Market world)	'The Drifting Fleet'	World Markets	New industrial neutrality

3.4 Common Themes:

There are a number clear themes which emerge from an analysis and overview of the existing scenarios for fisheries and aquaculture. As already stated, some of the issues which reoccur time and time again include the emphasis placed on **liberalised markets** and the level at which political power and decision making sits (EU, national, local). In most cases these particular attributes are used as major 'structuring' axes (figure 1), however in others (such as the personal visions of Bruun & Hukkinen 2002) these are simply part of a wider narrative.

Other issues which are raised in many of the existing storylines include global trade, including the **growing role of developing countries** and particularly China. This issue is addressed directly in the scenarios of Delgado et al. (2003) who provide explicit estimates of future demand for fish, as well as supply, imports and exports from different regions of the world up to the year 2027. Similarly Ross & Rosenthal (2006) describe four scenarios of fish product trade between developing countries and countries in the European Union. Other studies which address this issue include the FAO-SOFIA scenarios of 2004 (FAO 2004), which predict that there will be a global shortage of fish by 2015 and that the share of developing countries in world fish production is expected to increase from 75 percent in 1999/2001 to 81 percent by 2015. The Norwegian *Aquaculture-2020* scenarios (NRC 2005) consider the emergence of new markets for Norwegian fish products including China, India and Russia.

Ye (1999) estimated for the UN Food & Agriculture Organisation (FAO), the global demand for seafood in 2015 and 2030 based on extrapolations of trends in consumption and gross domestic product per capita. He predicted a doubling of the total demand between by 1995 (95 mt) and 2030 (183 mt) owing to population growth (for 40%) and economic growth (for 60%). The result would be an increase in total demand (of ca. 2.1% per year) and demand per capita (ca. 1.1% per year). Pauly et al. (2003) invested time in an extrapolation of long-term trends in global fisheries (reported by Watson & Pauly 2001 – *Nature 414:534*), as did Garcia & Granger (2005). These latter authors provided a detailed discussion of global and regional trends in supply and demand and concluded that Asia will become a net importer and Latin America a leading exporter. Also that rich countries, already net importers, will increase their trade deficit.

For many of the European 'futures' studies (also the *Fish 2050* visions for Australia – Kearney et al. 2003) the looming deficit in global fish supplies is mentioned as a 'spectre' which might lead to nationalistic policies and worries about maintaining and protecting indigenous fish supplies. As indicated in table 2, many such studies have put forward a vision which concentrates on food security, which also implies control over exports (though not necessarily of imports) and a vision of the oceans primarily as a place of food production. This includes the *Order from Strength* scenario of the 'Millenium Ecosystem Assessment, the *Security First* scenario of Pauly et al (2003) and UNEP, the '*Fortress Europe/Britain'* scenario of AFMEC (Pinnegar et al. 2006) and UK-*Net Benefits* (Prime Minister's Strategy Unit 2004), the '*Rich Sea'* scenario of GAUFRE (Maes et al. 2005) and the '*North Sea as a larder'* scenario of Pope (1989). The INRA (2007) "Une pisciculture de terroir sous le regard attentive des citoyens" scenario assumes that developing countries start to place greater emphasis on provisioning of their own markets in the face of increasing demographic pressure (growing populations and demand for protein). The decline in supplies reaching French markets lead to the revival of the national pisciculture industry, which becomes a recognized actor of the local development.

Another issue which has received considerable attention has been the perceived importance of **leisure and recreation**, whether it be the increasing profile of recreational fisheries or the increasing use of the oceans for other leisure activities, which might in-turn displace commercial fisheries and aquaculture. Several studies have proposed scenarios within which recreation becomes the major activity in the marine environment, these have included '*The North Sea as a playground'* (scenario A) of Pope (1989) and '*The Playful Sea'* of GAUFRE (Maes et al. 2005). Other studies (notably AFMEC, UNEP-GEO and the *Millennium Ecosystem Assessment*) have discussed recreational fishing under each scenario, with increased profile for this activity particularly under the *'Global Stewardship'* scenario which assumes more leisure time for Europeans, and better status for the fish stocks favoured by most recreational anglers. The UK-AFMEC study (Pinnegar et al. 2006), ELME (Langmead et al. 2007) and the Belgian-GAUFRE study (Maes et al. 2005) also discuss the development of coastal tourism including the development of tourism-associated infrastructure (which may help or hinder fisheries and aquculture) and the profile of ecotourism activities. The Irish '*Sea Change'* study (Marine Institute 2006) attempted to quantify the scale and economic importance of marine tourism and leisure, it then suggested research priorities in the sector, including a greater prominence of recreational fishing.

The future prospects with regard to recreational activities and tourism are often linked to climate change, in particular both Pope (1989) and Pinnegar et al. (2006) [UK-AFMEC] speculate about the warm-water fish that might enter the northern European waters and be attractive to sport fishermen. **Climate change** is another issue which is mentioned in virtually all of the 26 futures studies. Some studies have chosen to assume a similar pattern of long-term climate change for each of their future visions, notably the New Zealand *"Setting course for a sustainable future"* scenarios (PCE 1999)(a 3.5ºC rise in global temperatures assumed throughout). Other studies have assumed slightly different long term climate change patterns under each scenario.

Because many of the studies have utilised an architecture originally 'inherited' from the IPCC (IPCC 2000), it is perhaps not too surprising that climate usually forms a focus for future scenarios in the marine environment. Of the IPCC-SRES scenarios, the A1F1 scenario ('world markets') implies the fastest rate of climate change (sea temperature increase, sea level rise, acidification of the oceans, extreme weather events) whereas the B1('global sustainability') scenario implies the slowest rate of change and the uptake of global mitigation measures. It is important to state however, that the differences in predicted climate change for each IPCC scenario, and hence each fishery/aquaculture scenario based on these (table 2), are relatively minor in the short term (the next 25 years). Substantive differences are only expected at the time-scale of 50-100 years, and thus some of the visions of the future that imply major changes in local temperatures (e.g. some of those put forward by Pope 1989 for the North Sea) might seem a little fanciful.

Few of the studies focussing on the future of aquaculture have focussed on climate change in any great detail, however the Norwegian *Aquaculture 2020* (NRC 2005) scenarios did comment on 'climate and the environment' with significant climate change anticipated under some scenarios (*feed for everyone, markets with no frontiers*) but not under others (*aquaculture university, new industrial neutrality*). The INRA (2007) "Une pisciculture industrielle dans un contexte libéral" scenario anticipates the breeding of tropical fresh water species in France as an alternative to dwindling supplies from capture-fisheries an imports, and suggests that the culture of such species will benefit from favourable climatic conditions in the future.

Many of the futures studies anticipate **diversification of the fish products** being cultured or captured, because of changes in the environment, but also due to a shortage of 'traditional' products. The Norwegian *Aquaculture 2020* scenarios (NRC 2005) talk about new uses for waste products as well as new species in captivity. It, along with other studies (*Pew* scenarios – Pew Initiative 2003, Delgado et al. 2003) also considers the possible introduction of transgenic fish. The possibility to cultivate seafood tissue directly (as opposed to 'whole' organisms) is contemplated in some studies, despite the technological challenge and the probable market resistance (Kearney et al. 2002). The INRA (2007) "Néo consommateurs et néo producteurs revisitent le poisson d'élevage" scenario is unusual in that it anticipates greater emphasis on the keeping of ornamental and pet fish. The sales turnover of ornamental fish under this scenario exceeds that of cultured trout for human consumption, wheras under the "Une pisciculture industrielle dans un contexte libéral" scenario different ways of presenting existing fish products are explored, for example pre-packaged processed fish protein (surimi) versus recognisable whole animals.

Many of the fisheries scenarios (e.g. Garcia & Granger 2005) consider the targeting of hither to unexploited resources including krill and mesopelagic fishes. Others (such as Pauly et al. 2003, the Millennium Ecosystem Assessment (MEA 2005) and Pinnegar et al. 2006) concern themselves with the expansion of fisheries into deep water, such that very few fish resources anywhere in the world will be beyond the reach of commercial fisheries in the future. With new species being targeted by fisheries or reared in aquaculture facilities, this will necessitate innovation and advances in technology. However diversification is not the only a driver of technological advance, under certain socio-political conditions other driving forces come into play including a requirement for fishing gears or aquaculture facilities to be less damaging to the local environment, and/or the demand to be less wasteful (in processing and discarding etc.).

Technology is a theme which featured in all of the 26 studies. Under the UNEP-GEO scenarios (UNEP 2002) (and hence those of Pauly et al 2003), the *'Markets First'* scenario assumes that rapid technological advance is driven primarily by profits and markets, whereas advance is driven by government subsidies under the *'Policy First'* scenario and by public opinion under the 'Sustainability First' scenario. Slower technological progress is assumed under the introvert, nationalistic '*Security First'* scenario.

Some scenarios such as the 'Techno-Garden' vision of the Millennium Ecosystem Assessment (MEA 2005) suggest that technology may allow aquaculture to move offshore – where it will be less damaging to the environment. The Norwegian Aquaculture-2020 study (but also Delgado et al 2003) imagines technological developments along many different fronts, including new cage technologies, artificial feeds, new methods of rearing, trading and tracking fish products. The INRA (2007) "Néo consommateurs et néo producteurs revisitent le poisson d'élevage" scenario assumes that new technologies offer new opportunities and that public policies tend to support these, including new piscicultural foods, new species, closed-loop aquaculture systems, new biotechnologies and uses for fish products. This scenario also anticipates greater use of the internet for trading and tracking of fish products.

Technology will also play a vital role in the future development of capture fisheries (Delgado –et al. 2003). Technology can have positive implications, for example satellite-based systems are already used to track vessels and to check compliance, new technologies can help to ameliorate the damaging effects of particular gears, to assess the status of particular stocks and allow management in near 'real time'. On the other hand improvements in fishery technology, and particularly sophisticated acoustic and positioning devices, can facilitate the capture of every last fish in an area, and it has been estimated that modern trawlers operating in the North Sea are twice as efficient at catching cod compared to those 50 years ago and 50 times more efficient in comparison to sailing trawlers operating at the beginning of the 20^{th} Century (a phenomenon known as 'technological creep').

Garcia and Granger (2003) consider the new technologies which would be needed to catch and process unconventional fishery resources – also technological improvements in handling and storage. Forty years ago, Alverson & Wilimovsky (1964) provided a fictional picture of future (high-tech) fishing, much of which has still not been achieved even today and could well be taken as a possible future for the third millennium. Some of their fiction has become reality: for example, remote measurement of ocean temperature and other parameters; electronic single-fish detection and identification; pop-up, free-floating devices, transmitting their data to satellites (e.g. archival fish tags) and irradiation to preserve food items. Other predictions have not materialized to any extent.

Constanza (2000) developed scenarios which were very similar to those subsequently developed under the Millennium Ecosystem Assessment (MEA 2005). Constanza's four scenarios were based around the distinction between 'technological optimism' and 'technological scepticism'. The 'technological-optimist' world-view is one in which technological progress is assumed to be able to solve all current and future social problems. It is a vision of continued expansion by humans and their dominion over nature. However, there are two versions of this vision: (a) the positive version (the optimists were right), whereby technology solves all future energy and food demands and reduces the need for fossil-fuels; and (b) the negative version (the sceptics were right), whereby technological solutions do not materialise and there is widespread ecological collapse, flooding and famine.

Conflicting **spatial patterns of activity** are an issue that has been raised in many of the existing scenario studies. The Belgian GAUFRE scenarios (Maes et al. 2005) are the most overtly spatial of those considered here since the main aim of this particular project was "the development of a specific methodology for spatial planning at sea, with emphasis on interdisciplinary and public participation". However the limited availability of space for the growing number of activities now conducted in the marine environment are inherent (and often mentioned) in many of the other 'futures' studies. In 2005 the Netherlands (*Interdepartementaal Directeurenoverleg Noordzee* – IDON 2005) published an 'Integrated Management Plan for the North Sea', which attempted to take account of the different pressures in the Netherlands coastal waters. This study highlighted that "a decrease in space for fishing because more and more space is being used for functions that are incompatible or difficult to combine with fishing". Other studies have predicted the 'squeezing' out of fisheries and aquaculture under certain scenarios (notably UK-AFMEC and Pope 1989), and some have specifically predicted that the current, un-hindered access throughout Europe looks set to change with many areas set aside for conservation, energy generation or other activities. The Irish – *Sea Change* (Marine Institute 2006) report calls for a high quality, transparent system of marine spatial planning to facilitate the future development and management of marine related activities. Allied to this, some authors have considered the possibility that the 'burden of proof' might shift towards the fisheries and aquaculture sectors, whereby operators would be required to demonstrate that their particular activities will not be damaging to the environment or target resource by means of an 'Environmental Impact Assessment' prior to being granted access to a particular area of ocean. Such 'consents' are usually required for other users of the marine environment including oil companies, aggregate extraction operations and offshore power generators. The 'burden of proof' concept would also lead to a move away from the most damaging fishing gears, encouraging operators to seek more sustainable practices.

Several of the futures studies examined here make a distinction between activities 'onshore', 'inshore' and 'offshore', notably the Millennium Ecosystem Assessment (MEA 2005), the Irish – *Sea Change* report (Marine Institute 2006) and the Norwegian Aquaculture-2020 scenarios (NRC 2005). The Millennium Ecosystem Assessment in particular predicts different prospects of aquaculture development for each of the geographic domains depending on the particular scenario, whereas the Irish – *Sea Change* report states that the economic and technical feasibility of offshore locations for finfish culture has yet to be proven. An extended and long-term view of the Belgian-GAUFRE '*relaxed sea'* scenario could see the cultivation of marine organisms in closed production systems (fish, shellfish, algae etc.) on land in an effort to reduce environmental impacts in the oceans (Maes et al. 2005).

The increasing **power yielded by consumers** as well as environmental groups is a feature of many existing scenarios. Growing public awareness of environmental issues may foster political will and induce a change in consumer habits, and producers' attitudes (e.g. through ecolobelling) (Garcia & Granger 2005). Among the UNEP-GEO scenarios (UNEP 2002), the *'Policy First'* vision is most associated with public-private co-operation and 'top down' influences of the consumer on the producer. However the 'Sustainability First' vision also implies more participation of individuals and 'grass-roots' NGOs. Of the Norwegian *Aquaculture 2020* scenarios, the *'Feed for all'* vision assumes that consumers demand sustainable production –and questions are asked about using wild fish to feed to cultured fish. In the UK-AFMEC *Local Stewardship* scenario retailers and consumers place considerable emphasis on procurement of local supplies and there is rapid growth in small-scale organic and low input fish-farming. Under the *Global Commons* scenario retailers transmit consumer concerns to the fishing industry through ethical purchasing policies (Pinnegar et al. 2006). The INRA (2007) "Néo consommateurs et néo producteurs revisitent le poisson d'élevage" scenario, as it's name suggests, also focuses on the attitudes of consumers, wheras the INRA "Une pisciculture de terroir sous le regard attentive des citoyens" anticipates greater uptake of organic and sustainability ecolabels. The "Le renouveau du développement de la pisciculture en France et en Europe porté par une volonté politique" scenario suggests that greater certification of the products will develop, supplemented by ecolabels or labels such as "product of Europe". Certifications of companies develop and the ISO standards diversify to accompany new processes and procedures.

One final theme than has received much attention in nearly all of the earlier futures studies has been the **health benefits and the health risks** associated with eating seafood products. Among the (somewhat strange) visions put forward by Bruun & Hukkinen (2002), the authors included one scenario which concentrates on 'variability in fish consumption' as a result of health scares but also the promotion of fish as a healthy food. Other futures studies (notably the Irish- *Sea Change* Report – Marine Institute 2006) have addressed this issue but different assumptions about fish quality/safety have only rarely been incorporated into scenarios. Some scenario schemes assume more extensive inputs of chemicals, nutrients and contaminants under particular futures, for example the 'World Markets' and 'Fortress Britain' scenarios of UK-AFMEC (Pinnegar et al. 2006), the allied ELME scenarios and the 'Security –First' scenario of UNEP-GEO. Others predict more frequent occurrences of harmful algal blooms under particular scenarios (the '*Baltic algal blooms'* scenario of Bruun & Hukkinen, the 'markets-first' scenario of UNEP-GEO).

Public health issues surrounding fish consumption have direct impacts on trade, in that exporting countries will increasingly have to meet consumer demands for food safety in importing countries (Delgado et al. 2003). With regard to aquaculture, some scenario schemes assume less-intensive, low chemical input systems as well as a decrease in the use of antibiotics and pesticides.

Clearly, an improvement in the health status of the population is a major priority for many European nations. International experience shows that marine food products have a major beneficial impact on human health. It is also clear that marine organisms have a significant untapped potential to contribute to the development of 'functional foods' and drugs. The Irish *Sea Change* report of 2006 (Marine Institute 2006), suggests that by 2020 the marine sector in Ireland might be a major supplier of raw materials to the international food and biotechnology sectors. "A range of ailments and diseases including cancers, obesity, diabetes, and immunity development will be targeted using marine functional foods". Traditional marine food processing firms will become proficient in new processes designed to extract, separate, purify and package compounds of marine origin.

3.5 Shocks & Catastrophes:

The exploratory and synthetic approach used in most scenarios tends to assume that change occurs gradually along a single trajectory. Future states are seen as the logical outcome of an accumulation of changes over time, all pointing in the same broad direction. But not all change is like this. Change may take place slowly, or it may happen very suddenly as a result of major surprise events such as an earthquake or tsunami. If the change is slow it may be possible for one scenario to be completely superseded by another. If the change is sudden, then the question to be asked is "how 'resilient' a given scenario is to this sudden event?" Answering this question will be very difficult, mainly because large-scale, unanticipated events are, by their very nature, hard to foresee.

It is possible to differentiate between two distinct types of 'shock events': (a) those which occur very suddenly and inexplicably, e.g. meteorite strikes, and (b) 'break-point' events which follow a slow build-up (e.g. weakening and then sudden breakdown of the thermohaline circulation in the Atlantic). Generally, most systems (political or natural) are resilient to a point, but beyond a critical threshold ('tipping-point'), serious change and/or damage may ensue. Some 'shock events' occur only when the ecosystem is weakened by other factors, for example fish stocks which are otherwise resilient to occasional poor year classes associated with short-term climatic events, may collapse because fishing removes older age groups which provide some stability. Some 'shock events' (e.g. earth-quakes) are causes in themselves, others are consequences (e.g. tidal-waves may result from earthquakes).

Sometimes 'shock events' interact and have multiple impacts on the human and biological environment, e.g. sudden climate change can affect the transmission of diseases, the ability of exotic species to become established, or even catastrophic release of methane from gas-hydrates, all of which have secondary consequences. Some events have very short-term, localised impacts (e.g. oil spills or hurricanes), whilst others result in long-term, irreversible changes with global implications.

Very few of the 26 futures studies reviewed here take account of shocks and sudden catastrophes (although many acknowledge their existence), this is particularly so among the studies with a rigid architecture such as those featured in table 2. The UK-AFMEC study (Pinnegar et al. 2006) assembled an inventory of 'shock events', by consulting conventional and unconventional data sources, and through brainstorming workshops. Individuals from a wide range of stakeholder backgrounds were asked to list possible **low-probability high-impact events** that might conceivably impact upon the marine environment. Many different 'shock events' or 'discontinuities' were proposed, and these were categorised into four broad types: (1) those concerned with the human environment, (2) climatic events, (3) biological/ecological events, and (4) geological and astronomical events.

- Geological and astronomical events include earthquakes, tsunamis, volcanic eruptions, meteorite strikes and occasional catastrophic releases of methane from gas hydrate deposits.

- Biological and ecological events include sudden outbreaks of disease, invasions by exotic species, escapes from aquaculture facilities and toxic algal blooms.

- Climatic events include extreme storm-surges or 'rogue' waves, droughts or extreme precipitation, temperature 'spikes', a sudden breakdown in ocean currents such as the thermohaline circulation system.

- Events in the 'human environment' include war and associated damage to the environment (or respite from fishing), terrorism and possible contamination issues, sudden changes in social attitudes (e.g. health scares or changes in consumer tastes), new discoveries, fuel shortages and sudden economic recession (which influences industry and employment).

One of the few studies to include 'shock' events explicitly is that of Bruun & Hukkinen (2002), which includes a scenario whereby oil tankers collide, pollute the Baltic Sea and thereby greatly restrict the development of aquaculture in the region. The UNEP – GEO report (UNEP 2002) asks readers to "Imagine… a crash in circumpolar Antarctic krill stocks". It then goes on to elaborate on how society might respond under each of the four UNEP scenarios:

In the case of…

Markets First

- Some regulatory steps are taken, but market mechanisms are the prime response measures used — reducing krill demand by raising prices, and harvesting by raising costs.
- Harvesting switches to other species, including those that are not dependent upon krill themselves and may be competitors. Where these responses fail, the fishing industry abandons the area.
- It is widely presumed that krill stocks will in time recover, and that the adverse knock-on effects will turn out to be reversible.

Policy First

- Moratoria on krill harvesting are agreed to allow stock recovery.

- These steps are accompanied by reductions in fisheries activities across all target species.
- Major research effort is directed to understanding what has happened and underpinning policy responses.
- The regulatory regime for the marine environment is revised.

Security First

- Measures are taken to ban some operators from the region as a way to curb pressures on krill stocks.
- Market mechanisms are employed when they underpin the interests of key stakeholders in the region.
- In a bid for short-term 'use-it-or-lose-it' exploitation, harvesting switches to other species, including those expected to decline steeply as a result of krill stock collapse.
- Active management of the marine environment begins by seeding new krill stocks (including genetically modified types), enhancing nutrient levels and depressing predators or competitors.

Sustainability First

- There is an immediate closure of all krill fisheries pending recovery of stocks.
- Substantial reductions in other fisheries are introduced as a precautionary measure — although directed harvesting of particular predator populations is considered in some areas.
- A renewed effort is made to understand the functioning of the Antarctic marine environment.
- Negotiation begins for a new legal regime to manage the marine environment and regulate more limited harvesting when stocks have recovered.

In the Norwegian 'Aquaculture 2020' scenarios (NRC 2005) some kind of crisis is included in each of the five scenarios. Similarly in the *Fish to* 2020 scenarios of Delgado et al (2003) there is some consideration of supply shocks associated with climate variability. These include price spikes during times of shortage, for example during El Niño events. The UK *Net Benefits* report considered possible events which would have a high impact on the future but may or may not happen, and of all the shocks examined only sudden climate change was considered both serious and likely enough to be included throughout the analysis.

The authors of the *Millennium Ecosystem Assessment* (MEA 2005) acknowledge (on p8-10 of their report) that the MEA scenarios address incremental changes but fail to address thresholds, or the impact of large, extremely costly or irreversible changes in ecosystem services. This was also true of the FAO-SOFIA scenarios. Garcia & Granger (2005) talk about possible bifurcations and low-probability 'surprises', at which the future may change course. Among those listed, the authors mention economic factors such as collapse of the stock market or oil price shocks, both of which might greatly influence the future of fisheries and aquaculture.

3.6 Consultation & Stakeholder Participation:

The level of consultation over the structure, character and contents of the various scenarios varied appreciably across the 26 studies, and ranged from the personal views of one person (e.g. Pope 1989, Daan 1989) to very detailed storylines mapped out by an international panel of hundreds of expert scientists. Examples of the latter include the IPCC-SRES scenarios (IPCC 2000), UNEP-GEO (UNEP 2002) and the *Millennium Ecosystem Assessment* (MEA 2005) although the effort actually dedicated to marine scenarios has been comparatively small. These global studies have often involved quantitative modelling, and the outputs of these studies have been taken-up 'as read' (assumed to be correct) as part the storylines in other, less well resourced scenario studies (such as UK-AFMEC and ELME).

The elaboration of scenarios has often required large workshops involving relevant 'stakeholders' (e.g. UK-AFMEC, GAUFRE, *Aquaculture 2020*-Norway). As part of the New Zealand *Setting course for a sustainable future* project (PCE 1999) by contrast, the investigation team traveled from town to town meeting as many people as practicable (85 organizations including fisheries representatives, recreational fisheries, academics, environmental NGOs, rescue services, government agencies, tourist authorities, shipping agents, defense services). The great diversity of people reflected the diversity of marine environmental issues and interests. Each group and sector was consulted on the current issues and concerns relating to the marine environment, as well as those issues that will be relevant in the 21st century. Innovative solutions and creative practical ideas for managing the marine environment sustainably were of particular interest.

As part of the *Millennium Ecosystem Assessment* (MEA 2005) interviews with stakeholders were used to identify focal questions, key uncertainties, and cross cutting assumptions. In addition, the 'Scenario Guidance Team' conducted a series of interviews with potential 'users' to obtain input for developing the goals and focus of the scenarios.

The approach taken by the Netherlands National Council for Agricultural Research in their 1997 study *Fishing for research* (Jagtman et al. 1997) involved a two-step process of interviews with representatives from the field in order to develop a more precise view on the issue at hand, followed by a series of more generic workshops attended by representatives from the fishing industry, political parties, nature- and conservation groups, in order to map out future research requirements.

Some studies have primarily chosen to carry out workshops involving specialist 'experts' (e.g. ELME, *Fish to 2020,* AFSOUTH-France, UNEP-GEO). Sometimes this involved gathering views over a sustained period whereas in other instances it involved gathering views on the final document. With regard to the French study focussing on *Aquaculture and fisheries in southern countries,* the report was submitted for final reaction to a panel of experts from various origins; army, economics, research, private companies. Their remarks and recommendations were included in the revised report.

The *Fish to 2020* scenarios of Delgado et al. (2003) grew out of broader collaboration between IFPRI and the WorldFish Center that started with a consultative conference. This was attended by prominent fisheries policy analysts from developing countries, the purpose of the conference was to define the key policy research issues confronting fisheries in developing countries, and to help recommend a common agenda for policy research in fisheries.

As part of the UK-*Net Benefits Study* (Prime Minister's Strategy Unit 2004) a comprehensive list of potential drivers of the future UK sea fishing industry was drawn up with the help of both experts and stakeholders. Similarly in Ireland, the *Sea Change – A Marine Knowledge Research and Innovation Strategy* (Marine Institute 2006) was developed initially by experts but then the outcomes of this Foresight Exercise, were put through an intensive and wide-ranging stakeholder consultation process, including workshops, to further shape the strategy planning process.

3.7 Research drivers & priorities:

Most of the 26 future studies examined here did not consider research priorities and drivers in any great detail, and only those projects focussing specifically on science and technology provided a more thorough treatment of how research in the field of fisheries and aquaculture might need to look in the future (such as Ireland's *Sea Change* initiative*,* the Netherlands *Knowledge & Innovation Priorities* study*,* France's *Aquaculture & fisheries in southern countries: prospective analysis of the research demand by 2025*).

Some studies considered scientific infrastructure and organisational issues (e.g. New Zealand-*Setting course for a sustainable future*, UK-*Net Benefits*), whereas others considered science and technology as 'drivers' of change but not an outcome which might vary depending on the prevailing socio-economic conditions of the wider scenarios (an example being Constanza 2000 and the *Millennium Ecosystem Assessment*). Science, technology and research are mentioned throughout the UNEP-GEO 'outlook' (UNEP 2002), however this is mostly in the context of who will pay, the speed of advancement and the profile of research and development in shaping the future of fisheries and aquaculture.

The Norwegian *Aquaculture 2020* (NRC 2002) study provided a list of priority research areas (regardless of scenario), these included:

- Farming biology and technology
- New materials –new technologies
- Feed resources –new feed ingredients
- New species in aquaculture
- Health and welfare of aquaculture species
- Ethical and sustainable aquaculture production
- Safe and healthy seafood
- Sustainable use of the coastal zone
- Market and product development, transportation and logistics

The authors also considered how research might be organized and financed (e.g. by private companies or government institutes), the role of biotechnology and the level of international cooperation.

The Dutch study – *Knowledge and Innovation Priorities, Aspirations for the 21st Century* (NRLO 1998) made the following recommendations:

- Strengthen research into (further) valorisation possibilities of fish products.
- Appoint an 'innovation group' of scientists, technologists and entrepreneurs who will focus exclusively on 'marification' opportunities.
- Give an impetus to research, education and innovation to promote fish farming on land and in coastal zones.
- Strengthen the international component in Dutch and European fishery research.
- Encourage interdisciplinary research into alternative administrative arrangements for managing fish stocks and ensure intense participation by all stakeholders.
- Reduce the focus of biological research into commercially interesting fish species limited to the North Sea and extend basic and interdisciplinary knowledge on marine ecosystems generally, e.g. by taking a more active part in international research programmes in this field.
- Ensure that knowledge required for *Coastal Zone Management* is broadened in both research and education by achieving a programmed concentration of relevant parts of the knowledge infrastructure that is present in the Netherlands and in other countries.

The study also recognized that in meeting the challenges outlined above, it will be necessary to narrow the gap between 'research' and 'practice'. As for the government budget available for research into fisheries and aquaculture, the authors suggested that Dutch knowledge institutes currently focus strongly on North Sea fishing and on 'preservation' rather than expansion of existing cultures. The study therefore states that if the Netherlands has the ambition to make full use of the market potential, then the country will have to invest in a considerably broader range of research issues. This can only be a fruitful exercise if it is accompanied by a strengthening of partnerships with *different* knowledge institutes both at home and abroad.

The Australian Marine Science & Technology Plan from 1999 (COA 1999) defines twenty-nine objectives for the national effort in marine science, technology and engineering, through three Programs: Understanding the marine environment; Using and caring for the marine environment; Understanding and utilising the marine environment.

Among these 29 objectives, those of relevance to fisheries and aquaculture include:

- To ensure the maintenance of healthy and properly functioning ecosystems, through the development and application of effective monitoring and assessment procedures and sustainable management practices.
- To provide the scientific basis for the planning and implementation of sustainable multiple use management practices in our marine environment
- To improve the productivity and sustainability of wild harvest fisheries, and to improve understanding of the relationship between fished stocks and the ecosystems that support them
- To improve the sustainability, productivity and environmental performance of aquaculture
- To ensure the availability of an appropriate skills base in marine science, technology and engineering
- To provide the physical infrastructure required for the continuity and improved performance of marine science, technology and engineering in Australia
- To implement systematic, coordinated and long-term marine observational programs
- To achieve better coordination of marine data management
- To build professional expertise and knowledge through increased involvement in regional and global marine science and technology programs
- To promote, within the community, the importance of marine science, technology and engineering for sustainable economic growth and quality of life

Canada's "*Marine & Ocean Industry Technology Roadmap"* (NRC 2003) suggests there are several areas of technological challenge and opportunity, which are key to the sustainability and enhancement of capture fisheries in the future:

More scientific research involving innovative approaches aimed at better assessing:

- Fish stock levels need to be done in a timely and more reliable manner; and
- The impact of external factors such as fishing, environment, climate change, disease, and predation on life cycles and habits needs to be studied.

Innovative technologies are required that enable fishers to harvest fish "smarter" i.e. reducing or eliminating by-catch and spawning / immature stock rather than efficiency improvements such as increasing catch through indiscriminate harvesting.

There is a need for innovation on a number of fronts to widen the range of viable aquaculture species suited to Canadian waters. This would increase the long term growth potential for the industry, open whole new geographic areas to development, and create much needed jobs particularly in rural and Northern areas. Given the declining availability of wild fish stocks worldwide, the availability of fishmeals and oils presents serious limitations, which may in time affect the growth of the industry, or its present-day economics (NRC 2003)

Some long-term research priorities for fish capture, seafood harvesting and aquaculture include:

(Aquaculture)

- Biological: single-sex (non-reproductive) animals and genetically engineered for containment
- Improving supply or organic feed ingredients (enzymatic modification of feed stock)
- Applied aquaculture biotechnology (diagnostics, genetic trait tracking; immunology/nutraceuticals)
- Fish friendly turbines for tidal power generation
- Bio-processing technology (i.e. enzymes)
- Genetic engineering GMOs (acceptability issues apply) study benefits and risks

- Waste management
- Fish "health" technology (e.g. vaccination technology)
- Bio-engineer effects of domestic salmon on wild stocks to identify and prevent transfers

(Seafood harvesting)

- Safety issues (fishing fleet renewal)
- Marine ecosystem modelling
- Biological science and oceanography
- Chemical science
- Habitat mapping
- Tools and signal processing for detecting species that are under farmed or not farmed.
- Identification (rapid screening techniques, monitoring path and environment).
- Humane non-stressful fish-killing devices, i.e. "stun and bleed" (perception and quality)
- Applied aquaculture biotechnology (diagnostics, genetic trait tracking; immunology/nutraceuticals)
- Economic & safe fishing vessels (65, 45 ft. rules)
- Fuel efficient vessel design (fuel cells)

The Irish study *Sea Change: a marine knowledge & innovation strategy for Ireland* (Marine Institute 2006) outlined a large number of specific research priorities (RTDI requirements) for fin-fish aquaculture, shellfish aquaculture and capture fisheries (as well as seaweed research), and these represent a very good starting point for a list of research priorities in Europe as a whole:

Capture Fisheries sector –

- Develop strategies/procedures to assess and integrate fishing industry knowledge into scientific assessment and advisory process
- Develop user-friendly interactive models that can be used to discuss the implications of different management strategies and current scientific advice with Regional Advisory Councils (RACs) and other stakeholders
- Continue to improve the transparency of the scientific assessment and advisory process in relation to national and international assessment practices
- Map the spatial and temporal distribution of spawning and nursery areas for fish stocks in the waters around Ireland and integrate with seabed survey data and oceanographic data
- Expand knowledge of fishing impacts on target stocks and non-target species (through by-catch and discarding), and the impacts on food-web interactions, habitats and biodiversity
- Study the biological basis of existing management areas through tagging and genetic research
- Study the biological basis of existing management areas through tagging and genetic research
- Conduct assessments and provide clear, reliable and impartial advice on stocks of economic importance to Ireland, both nationally (e.g. inshore stocks) and internationally (i.e. fish stocks managed under the CFP and migratory species)
- Develop and trial practical assessment methods that use both commercial fleet data sets and survey data sets
- Model impact of fishing gear changes, closed areas and seasons, and fleet activity (e.g. decommissioning) on stock assessment and advice
- Develop mixed fishery harvest control rules and long-term management scenarios, and model their impacts
- Develop strategies and procedures to assess and integrate ecosystem knowledge into current management models used to provide scientific advice

- Research and analyse the socioeconomic factors that influence the day-to-day behaviour of vessel owners/skippers with regard to investment decisions, target species, choice of gear, fishing grounds, level of discarding etc. Ensure that the results feed into scientific assessment and management plans
- Research and develop technology in the area of fishing gear and practices to improve gear selectivity and reduce the impact of gear on ecosystems
- Research the potential impact of various management regimes (e.g. artificial habitats and Marine Protected Areas—MPAs) for fish stock recovery
- Integrate and add value to the disparate marine data sets (fisheries, oceanography, environmental and others) that exist both nationally and internationally

Fin-fish Aquaculture sector -

- Market research for organic products and finfish produced by ‘environmentally friendly’ means
- Research opportunities to add functional food properties to organic production
- Integrate monitoring, management and licensing regimes into a seamless process
- Evaluate and refine codes of practice/protocols for aquaculture management and monitoring
- Develop and refine Single Bay Management/CLAMS and the implementation of integrated single bay-based code of practice for on-farm health management
- Contribute to research, development and licensing of appropriate vaccines for key viral diseases and parasites (PD, ISA, sea lice)
- Develop effective carrying capacity modelling capability to support environmentally sustainable aquaculture
- Improve environmental forecast monitoring methodology
- Develop management and mitigation measures for harmful phytoplankton and zooplankton (jellyfish)
- Assess system for development of an indicator/incentive based management system that will reward operators implementing environmentally sound best management practice, yet optimize production capacity
- Develop/transfer technology to assist with cage development and management systems, including ancillary technology needs (cages/feed systems, telemetry and integrated marine engineering/design systems)
- Develop ‘test-bed’ sites for technology evaluation
- Use of R&D and technology transfer to commercialise hatchery, juvenile and on-growing stages of turbot, halibut and char production (f/w + s/w)
- Continue the development of perch production (f/w)
- Develop appropriate cage-based grow-out technologies for cod
- Scale up and commercialise existing shore-based hatchery technology
- Develop broodstock programmes for screening native species as suitable aquaculture strains
- Promote R&D in other white fish and related technologies. Develop the necessary broodstock programmes with view to culture potential
- Adapt and develop technology for Irish needs in development of onshore fish farming

Shell-fish Aquaculture sector -

- Carry out applied research on biomass, seed availability and optimisation of production methods (e.g. wild mussel seed) as inputs to a science-based management programme
- Develop dynamic nutrient and/or chlorophyll driven carrying capacity models for key production bays
- Applied research and innovation in the mechanisation and improved efficiency of all shellfish culture systems (mussels, Gigas Oyster, Edulis (Native) Oyster).

- New Species. Selective breeding programmes for abalone, development of indigenous feed supply (seaweed based) for both abalone and urchins, refinement of re-circulation technology for shore-based cultivation
- Foster R&D linkages with international experts on shellfish health, including participation in joint international R&D projects on diseases such as Bonamia in native oysters, brown ring disease of clams, and Summer Mortality Syndrome (SMS) in Gigas oysters
- Investigate/adapt new procedures/technology for moving some production to offshore locations. Identify areas of high productivity offshore to allow for further development
- Research into alternatives to bio-assays and development of rapid assays/field tests for biotoxins
- Remote monitoring/predictive systems for Harmful Algal Bloom (HAB) occurrences
- Interactions between shellfish aquaculture and the environment, with an emphasis on inter-tidal culture/bird interaction

The Irish study also introduces the concept of 'Discovery Research' which includes development of leading edge, multidisciplinary research and encompasses programmes which focus on Marine Biotechnology and Marine 'Functional Foods' (Marine Institute 2006).

Priorities under the Marine Biotechnology field include:

- Identification and analysis of biodiversity 'hotspots' in the Irish marine environment
- Implementation of a sampling, processing and storage procedure for marine biomaterials
- Enhancement of marine taxonomic capabilities
- Implementation of high-throughput systems for metagenomics
- Establishment of a chain of primary screening activities to identify novel bioactivities for compounds developed
- Development of current core capabilities and collaborations to purify and elucidate the structure of novel compounds with bioactivity
- Enhancement of core capabilities in synthetic chemistry to design new drugs based on novel compounds with bioactivity
- Establishment of a chain of secondary screening tests to examine the safety and toxicology of the novel compounds with bioactivity

For each research priority (RTDI requirement) the study suggested key outputs, the 'competencies' required, current strengths and any areas of research which require strengthening, also any gaps in the national research capabilities.

3.8 What happened next?

Many of the scenario documents provide recommendations, but these are quite variable in their 'target' and their focus.

Some recommendations concern necessary institutional changes for example the French *Aquaculture et pêche dans les pays du Sud* (IFREMER 2002) report which provided new research orientations in Ifremer, as well as proposals for organising and improving reactivity within the institute and for increasing capacity to satisfy demand and improve to competitively in the future. Other recommendations highlight new research areas, for example Delgado et al. (2003) provided 'Entry Points for Policy Action' also 'Priorities for Future Policy Research'.

Some recommendations concern only the uptake of the scenarios themselves, for example the UK-AFMEC report:

- Construction of a centralized 'marine scenarios gateway' on the internet to assist stakeholders in developing and assessing possible adaptation strategies,
- Creative workshops using the AFMEC scenarios as a discussion tool.

- Establishment of a 'scientific forum', to discuss how the AFMEC scenarios might be quantified further.

Other recommendations were directed at specific persons, for example the New Zealand *'Setting course for a sustainable future'* (PCE 1999) study with suggestions directed to the New Zealand Minister of Environment, Conservation and Fisheries, the Minister of Research, Science and Technology and the Prime Minister.

Some reports provide a translation of 'what this means' for individual stakeholder groups. The Millennium Ecosystem Assessment (MEA 2005) for example, provided 'main messages, 'synthesis for key stakeholders', and 'lessons learnt', including "implications for: (1) Convention on Biological Diversity, (2) national governments, (3) communities & NGOs, (4) the private sector. The UNEP-GEO (UNEP 2002) report offers "i*mplications for….*" specific regions of the world, also a summary of "*lessons learnt*" and "*reflections on the use of scenarios".* The specific lessons learnt were:

- Contrasting yet plausible stories can be told for how the world and its regions will develop in the next 30 years; each has fundamentally different implications for the environment.
- There can be significant delays between human actions, including policy decisions, and associated impacts on the environment.
- Achieving widely agreed environmental and social goals will require dramatic and coordinated action starting now and continuing for a number of years. Steps must include policies based on prevention and adaptation.
- Important linkages exist between different environmental issues and between environmental and broader social issues.
- The establishment of strong institutions for environmental governance is a prerequisite for almost all other policies.

Some scenarios had a big impact on government fisheries/aquaculture policy and influenced subsequent regulations or the re-structuring of the national fisheries fleet (e.g. the UK – *Net Benefits* report (Prime Minister's Strategy Unit 2004), which included quantitative analyses of profits, revenues and costs in different fleet segments).

4 Bibliography

Alverson, D. L. & Wilimovsky, N. J. 1964 Prospective developments in the harvesting of marine fisheries. In Modern fishing gear of the world. Part 3. Technical research (ed. H. Kristjonsson), pp. 583–590. London: Fishing News (Books) Ltd.

Beckett, J. S. 1998 World marine fisheries 1975–2025: fifty years of change. J. Northw. Atl. Fish. Sci. 23, 221–232.

Berkhout, F. and Hertin, J. (2002) Foresight Futures Scenarios: developing and applying a participative strategic planning tool. Greenleaf Publishing, Greener Management International (GMI), 37: 37-52.

Bruun, H. & Hukkinen, J. (2000) Scenarios as radical alternatives: the case of aquaculture in the Finnish Archipelago Sea.

COA (1999) Australia's Marine Science and Technology Plan. Science and Technology Policy Branch, Department of Industry, Science and Resources, Canberra, Commonwealth of Australia. 146pp.

Constanza, R. (2000) Visions of alternative (unpredictable) futures and their use in policy analysis. *Conservation Ecology,* 4 (1), 5. www.ecologyandsociety.org/vol4/iss1/art5/ online publication.

Cury, P. & Cayre´, P. 2001 Hunting became a secondary activity 2000 years ago: marine fishing did the same in 2021. Fish Fish. 2, 162–169.

Daan, N. 1989 The ecological setting of the North Sea. Dana, 8, 17–31.

Defra (2007a) Fisheries 2027 – a long-term vision for sustainable fisheries. Department for Environment, Food & Rural Affairs, UK. 18pp.

Defra (2007b) Delivering Fisheries 2027 – towards an implementation plan. Department for Environment, Food & Rural Affairs, UK. 2 October 2007. 16pp.

Delgado, C.L., Wada, N., Rosegrant, M.W., Meijer, S., Ahmed, M. (2003) Fish to 2020: supply and demand in changing global markets. International Food Policy Research Institute & World Fish Centre, Manilla. 226pp.

FAO (2004) The State of World Fisheries & Aquaculture – 2004. Part 4 – Outlook, pp 141-153. FAO Fisheries Department, Food & Agriculture Organisation of the United Nations, Rome.

Garcia, S.M. & Grainger, R.J.R. (2005) Gloom and doom? The future of marine capture fisheries. *Phil. Trans. R. Soc. B.,* 360, 21–46.

Grübler, A. and Nakicenovic, N. (2001) Identifying dangers in an uncertain climate: We need to research all the potential outcomes, not try to guess which is likeliest to occur. *Nature*, 412, 15 Correspondence.

IDON (2005) Integral Beheerplan Noordzee 2015. *Interdepartementaal Directeurenoverleg Noordzee* – IDON, 313pp.

IFREMER (2002) Aquaculture et pêche dans les pays du Sud : analyse prospective 2025 de la demande en recherche. Jacques Fuchs coordinator, 2002. J.P. Blancheton, J. Fuchs, D. Lacroix, N. Lacroix, Ph. Lemercier, J. Marin, L. Antoine*. Ed. Ifremer, Bilans & Prospectives, 126 p*.

Ikeda, H. 1998 On the future economy of capture fisheries and the future consumer market for fish. J. Northw. Atl. Fish. Sci. 23, 185–189.

INRA (2007) 5 Scénarios pour la pisciculture Français en 2021. Commission Filière Poissons. Institut National de la Recherce Agronomique, 24pp. www.inra.fra/coordination_piscicole

IPCC (2000) *Special Report on Emmissions Scenarios (SRES).* Nakicenovic, N. & Swart, R. (Eds.). International Panel on Climate Change, Cambridge University Press, Cambridge, UK 612pp.

Jagtman, E., Buisman, E., de Jons, P., Schütte, P. (1997) Fishing for research – a scenarios study on fisheries and ecosystem. National Council for Agricultural Research, The Hague, Netherlands. Report 97/35.

Kearney, B., Foran, B., Poldy, F, Lowe, D. (2003) Modelling Australia's Fisheries to 2050: Policy and Management Implications. Fisheries Research and Development Corporation, Australia.

Langmead, O., McQuatters-Gollop, A., Mee, L.D. (2007) European lifestyles and marine ecosystems: exploring challenges for managing Europe's seas. 43pp. University of Plymouth Marine Institute, Plymouth UK.

Maes, F., Cliquet, A., Degraer, S., Derous, S., De Wachter, B., Douvere, F., Leroy, D., Schrijvers, J., Van Lancker, V., Verfaillie, E., Volckaert, A. (2005) *A Flood of Space: Towards a Spatial Structure Plan for Management of the North Sea.* Belgian Science Policy, Belgium. 204pp.

Marine Institute (2006) Sea Change: A Marine Knowledge, Research & Innovation Strategy for Ireland 2007–2013 (Volumes I & II). Marine Institute, Galway Ireland. 139 + 202pp.

MEA (2005) Ecosystems & Human Well Being: Scenarios Volume 2. Findings of the Scenarios Working Group of the Millennium Ecosystems Assessment, Carpenter S.R., Pingali P.L., Bennett E.M., Zurek M.B. (eds.). Island Press, Washington, 560pp.

Meadows D. and Meadows, D.H. (1979) The Limits to Growth: A Report for the Club of Rome's Project on the Predicament of Mankind. Macmillan; New Ed edition. 208pp.

NRC (2003) Marine and Ocean Industry Technology Roadmap. Research Council Canada. www.nrc-cnrc.gc.ca/clusters/ocean/home_e.html

NRC (2005) Aquaculture 2020: transcending the barriers – as long as… The Research Council of Norway (NRC).

NRLO (1998) "Fisheries and Aquaculture Knowledge and Innovation Priorities Aspirations for the 21st Century". National Council for Agricultural Research, NRLO-report nr. 98/18E, The Hague, 35pp.

OST (1999) *The use of scenarios in Foresight.* An information document prepared for the OST by Professor David Stout. www.foresight.gov.uk.

Pauly, D., Alder, J., Bennett, E., Christensen, V., Tyedmers, P. Watson, R. (2003) The future for fisheries. *Science,* 302: 1359-1361.

PCE (1999) *Setting course for a sustainable future: the management of New Zealand's marine environment*. Office of the Parliamentary Commission for the Environment, New Zealand. 111pp.

Pew Initiative (2003) *Future Fish: Issues in Science and Regulation of Transgenic Fish.* Pew Initiative on Food and Biotechnology, Washington, 71pp

Pinnegar, J.K., Viner, D., Hadley, D., Dye, S., Harris. M., Berkout, F. and Simpson, M. (2006) Alternative future scenarios for marine ecosystems: technical report. Centre for Environment, Fisheries & Aquaculture Science, Lowestoft Laboratory, UK. 109pp.

Pittock, A.B., Jones, R.N. Mitchell, C.D. (2001) Probabilities will help us plan for climate change. *Nature*, 413: 249. Correspondence.

Prime Minister's Strategy Unit (2004) *Net benefits: a sustainable and profitable future for UK fishing.* Prime Minister's Strategy Unit, Cabinet Office, UK. 168pp. www.number-10.gov.uk/su/fish/index.htm

Roth, E. & Rosenthal, H. (2006) Fisheries and aquaculture industries involvement to control product health and quality safety to satisfy consumer-driven objectives on retail markets in Europe. *Marine Pollution Bulletin* 53: 599–605.

Rowe and Wright (1999): The Delphi technique as a forecasting tool: issues and analysis. *International Journal of Forecasting*, Volume 15, Issue 4, October 1999.

Rowe and Wright (2001): Expert Opinions in Forecasting. Role of the Delphi Technique. In: Armstrong (Ed.): *Principles of Forecasting: A Handbook of Researchers and Practitioners*, Boston: Kluwer Academic Publishers.

Schneider, S.H. (2001) What is 'dangerous' climate change? *Nature,* 411: 17 – 19.

Shackley, S. and Wood, R. (2001) Socio-economic scenarios for use in regional climate change impact and response studies (RegIS) in East Anglia and the North west if England. In: UKCIP (2001)3 Socio-economic scenarios for climate change impact assessment: a guide to their use in the UK Climate Impacts Programme. UKCIP, Oxford. 103-119pp.

UNEP (1998) UNEP Handbook on methods for climate change impact assessment and adaptation studies (Eds. Burton, I., Feenstra, J.F., Smith, J.B., Tol, R.S.J) Version 2.0. United Nations Environment Program and Institute for Environmental Studies, Vrije Universiteit Amsterdam.

UNEP (2002) Global Environment Outlook 3: Past, Present and Future Perspective. Outlook 2002-2032, pp 320-400. United Nations Environment Programme. Earthscan Publications Ltd., London. 277 pages.

Ye, Y. 1999 Historical consumption and future demand for fish and fishery products: Exploratory calculations for the years 2015/2030. FAO Fisheries Circular 946, 31.